

ANALYSIS OF STRONG DECAYS OF THE CHARMED MESONS $D(2550)$, $D(2600)$, $D(2750)$ AND $D(2760)$

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Abstract

In this article, we study the strong decays of the newly observed charmed mesons $D(2550)$, $D(2600)$, $D(2750)$ and $D(2760)$ with the heavy quark effective theory in the leading order approximation, and tentatively identify the $(D(2550), D(2600))$ as the $2S$ doublet $(0^-, 1^-)$ and the $(D(2750), D(2760))$ as the $1D$ doublet $(2^-, 3^-)$, respectively. The identification of the $D(2750)$ and $D(2760)$ as the same particle with $J^P = 3^-$ is disfavored.

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1 Introduction

Recently the Babar collaboration observed four excited charmed mesons $D(2550)$, $D(2600)$, $D(2750)$ and $D(2760)$ in the decay channels $D^0(2550) \rightarrow D^{*+}\pi^-$, $D^0(2600) \rightarrow D^{*+}\pi^-$, $D^+\pi^-$, $D^0(2750) \rightarrow D^{*+}\pi^-$, $D^0(2760) \rightarrow D^+\pi^-$, $D^+(2600) \rightarrow D^0\pi^+$ and $D^+(2760) \rightarrow D^0\pi^+$ respectively in the inclusive $e^+e^- \rightarrow c\bar{c}$ interactions at the SLAC PEP-II asymmetric-energy collider [1], see Table 1. The Babar collaboration also analyzed the helicity distributions to determine the spin-parity, and suggested that the $(D(2550), D(2600))$ (denoted as $(D', D^{*'})$) respectively in Table 2) may be the $2S$ radial excitation of the (D, D^*) , and the $D(2750)$ and $D(2760)$ may be the D -wave states. Furthermore, the Babar collaboration measured the following ratios of the branching fractions:

$$\begin{aligned} \frac{\text{Br}(D_2^*(2460)^0 \rightarrow D^+\pi^-)}{\text{Br}(D_2^*(2460)^0 \rightarrow D^{*+}\pi^-)} &= 1.47 \pm 0.03 \pm 0.16, \\ \frac{\text{Br}(D(2600)^0 \rightarrow D^+\pi^-)}{\text{Br}(D(2600)^0 \rightarrow D^{*+}\pi^-)} &= 0.32 \pm 0.02 \pm 0.09, \\ \frac{\text{Br}(D(2760)^0 \rightarrow D^+\pi^-)}{\text{Br}(D(2750)^0 \rightarrow D^{*+}\pi^-)} &= 0.42 \pm 0.05 \pm 0.11. \end{aligned} \quad (1)$$

In the heavy quark limit $m_Q \rightarrow \infty$, the heavy-light mesons $Q\bar{q}$ can be classified in doublets according to the total angular momentum of the light degrees of freedom \vec{s}_ℓ , $\vec{s}_\ell = \vec{s}_{\bar{q}} + \vec{L}$, where the $\vec{s}_{\bar{q}}$ is the spin of the light antiquark \bar{q} and the \vec{L} is the orbital angular momentum of the light degrees of freedom [2, 3]. In the quark models, we usually use the n to denote the radial quantum number. In the case $n = 1$, for $L = 0$, the doublet (P, P^*) have the spin-parity $J_{s_\ell}^P = (0^-, 1^-)_{\frac{1}{2}}$; $L = 1$, the two doublets (P_0^*, P_1') and (P_1, P_2^*) have the spin-parity $J_{s_\ell}^P = (0^+, 1^+)_{\frac{1}{2}}$ and $(1^+, 2^+)_{\frac{3}{2}}$ respectively; $L = 2$, the two doublets (P_1^*, P_2) and (P_2^*, P_3) have the spin-parity $J_{s_\ell}^P = (1^-, 2^-)_{\frac{3}{2}}$ and $(2^-, 3^-)_{\frac{5}{2}}$.

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	Mass [MeV]	Width [MeV]	Decay channel
$D^0(2550)$	$2539.4 \pm 4.5 \pm 6.8$	$130 \pm 12 \pm 13$	$D^{*+}\pi^-$
$D^0(2600)$	$2608.7 \pm 2.4 \pm 2.5$	$93 \pm 6 \pm 13$	$D^+\pi^-, D^{*+}\pi^-$
$D^0(2750)$	$2752.4 \pm 1.7 \pm 2.7$	$71 \pm 6 \pm 11$	$D^{*+}\pi^-$
$D^0(2760)$	$2763.3 \pm 2.3 \pm 2.3$	$60.9 \pm 5.1 \pm 3.6$	$D^+\pi^-$
$D^+(2600)$	$2621.3 \pm 3.7 \pm 4.2$	93	$D^0\pi^+$
$D^+(2760)$	$2769.7 \pm 3.8 \pm 1.5$	60.9	$D^0\pi^+$

Table 1: The experimental results from the Babar collaboration.

respectively; where the superscript P denotes the parity. The $n = 2, 3, 4, \dots$ states are clarified by the analogous doublets, for example, $n = 2$, $L = 0$, the doublet $(P', P^{*'})$ have the spin-parity $J_{s_\ell}^P = (0^-, 1^-)_{\frac{1}{2}}$; $n = 2$, $L = 1$, the two doublets $(P_0^{*'}, P_1^{*'})$ and $(P_1', P_2^{*'})$ have the spin-parity $J_{s_\ell}^P = (0^+, 1^+)_{\frac{1}{2}}$ and $(1^+, 2^+)_{\frac{3}{2}}$ respectively.

The helicity distributions favor identifying the $D^0(2550)$ as the 0^- state, the $D^0(2600)$ as the 1^- , 2^+ , 3^- state, and the $D^0(2750)$ as the 1^+ , 2^- state [1]. From the Review of Particle Physics [4], we can see that only six low-lying states, D , D^* , $D_0(2400)$, $D_1(2430)$, $D_1(2420)$ and $D_2(2460)$ are established, while the $2S$ and $1D$ states are still absent. The newly observed charmed mesons $D(2550)$, $D(2600)$, $D(2750)$ and $D(2760)$ may be tentatively identified as the missing $2S$ and $1D$ states.

The mass is a fundamental parameter in describing a hadron, in Table 2, we present the predictions from some theoretical models, such as the relativized quark model based on a universal one-gluon-exchange-plus-linear-confinement potential [5], the semirelativistic quark potential model [6], the relativistic quark model includes the leading order $1/M_h$ corrections [7], the QCD-motivated relativistic quark model based on the quasipotential approach [8], for comparison. From the Table, we can see that the masses of the $D(2550)$, $D(2600)$ and $D(2750)$, $D(2760)$ lie in the regions of $2S$ and $1D$ states, respectively.

In Ref.[9], Sun et al study the strong decays of the $D(2550)$, $D(2600)$ and $D(2760)$ in the 3P_0 model, and identify the $D(2600)$ as a mixture of the $2^3S_1 - 1^3D_1$ states and the $D(2760)$ as either the orthogonal partner of the $D(2600)$ or the 1^3D_3 state. In Ref.[10], Zhong studies the strong decays of the $D(2550)$, $D(2600)$ and $D(2760)$ in a chiral quark model, and identifies the $D(2760)$ as the 1^3D_3 state and the $D(2600)$ as the low-mass mixing state of the $1^3D_1 - 2^3S_1$ states.

In this work, we study the strong decays of the newly observed charmed mesons with the heavy quark effective theory in the leading order approximation to distinguish the different identifications. There have been several works using the heavy quark effective theory to identify the excited D_s mesons, such as the $D_s(3040)$, $D_s(2700)$, $D_s(2860)$ [11, 12, 13, 14].

The article is arranged as follows: we study the strong decays of the newly observed charmed mesons with the heavy quark effective theory in Sect.2; in Sect.3, we present the numerical results and discussions; and Sect.4 is reserved for our conclusions.

	$n L s_\ell J^P$	Experiment [1, 4]	GI [5]	MMS [6]	PE [7]	EFG [8]
D	$1 S \frac{1}{2} 0^-$	1867	1880	1869	1868	1871
D^*	$1 S \frac{1}{2} 1^-$	2008	2040	2011	2005	2010
D_0^*	$1 P \frac{1}{2} 0^+$	2400	2400	2283	2377	2406
D_1'	$1 P \frac{1}{2} 1^+$	2427	2490	2421	2490	2469
D_1	$1 P \frac{3}{2} 1^+$	2420	2440	2425	2417	2426
D_2^*	$1 P \frac{3}{2} 2^+$	2460	2500	2468	2460	2460
D_1^*	$1 D \frac{3}{2} 1^-$? 2763	2820	2762	2795	2788
D_2	$1 D \frac{3}{2} 2^-$? 2752		2800	2833	2850
$D_2'^*$	$1 D \frac{5}{2} 2^-$? 2752			2775	2806
D_3	$1 D \frac{5}{2} 3^-$? 2763	2830		2799	2863
D'	$2 S \frac{1}{2} 0^-$? 2539	2580		2589	2581
$D^{*'} $	$2 S \frac{1}{2} 1^-$? 2609	2640		2692	2632

Table 2: The masses of the charmed mesons from different quark models compared with experimental data, and the possible identifications of the newly observed charmed mesons.

2 The strong decays with the heavy quark effective theory

In the heavy quark effective theory, the spin doublets can be described by the effective super-fields H_a , S_a , T_a , X_a and Y_a , respectively [15],

$$\begin{aligned}
H_a &= \frac{1 + \not{v}}{2} \{ P_{a\mu}^* \gamma^\mu - P_a \gamma_5 \} , \\
S_a &= \frac{1 + \not{v}}{2} \{ P_{1a}^{\prime\mu} \gamma_\mu \gamma_5 - P_{0a}^* \} , \\
T_a^\mu &= \frac{1 + \not{v}}{2} \left\{ P_{2a}^{\mu\nu} \gamma_\nu - P_{1a\nu} \sqrt{\frac{3}{2}} \gamma_5 \left[g^{\mu\nu} - \frac{\gamma^\nu (\gamma^\mu - v^\mu)}{3} \right] \right\} , \\
X_a^\mu &= \frac{1 + \not{v}}{2} \left\{ P_{2a}^{*\mu\nu} \gamma_5 \gamma_\nu - P_{1a\nu}^* \sqrt{\frac{3}{2}} \left[g^{\mu\nu} - \frac{\gamma^\nu (\gamma^\mu - v^\mu)}{3} \right] \right\} , \\
Y_a^{\mu\nu} &= \frac{1 + \not{v}}{2} \left\{ P_{3a}^{\mu\nu\sigma} \gamma_\sigma - P_{2a}^{\prime*\alpha\beta} \sqrt{\frac{5}{3}} \gamma_5 \left[g_\alpha^\mu g_\beta^\nu - \frac{\gamma_\alpha g_\beta^\nu (\gamma^\mu - v^\mu)}{5} - \frac{\gamma_\beta g_\alpha^\mu (\gamma^\nu - v^\nu)}{5} \right] \right\} \quad (2)
\end{aligned}$$

where the heavy field operators contain a factor $\sqrt{M_P}$ and have dimension of mass $\frac{3}{2}$. The ground state and radial excited state heavy mesons with the same heavy flavor have the same spin, parity, time-reversal and charge conjunction properties except for the masses, and can be denoted by the super-fields: H_a , H_a' , H_a'' , \dots ; S_a , S_a' , S_a'' , \dots ; T_a , T_a' , T_a'' , \dots ; etc, where the superscripts \prime , $''$ and $'''$ denote the first, the second and the third radial excited states, respectively. With a simple replacement of the components P_a , P_a^* , P_{0a}^* , \dots to the corresponding radial excited states P_a' , $P_a^{*'}$, $P_{0a}^{*'}$, \dots , we can obtain the corresponding super-fields H_a' , S_a' , \dots .

The light pseudoscalar mesons are described by the fields $\xi = e^{\frac{i\mathcal{M}}{f_\pi}}$, where

$$\mathcal{M} = \begin{pmatrix} \sqrt{\frac{1}{2}}\pi^0 + \sqrt{\frac{1}{6}}\eta & \pi^+ & K^+ \\ \pi^- & -\sqrt{\frac{1}{2}}\pi^0 + \sqrt{\frac{1}{6}}\eta & K^0 \\ K^- & \bar{K}^0 & -\sqrt{\frac{2}{3}}\eta \end{pmatrix}.$$

At the leading order, the heavy meson chiral Lagrangians $\mathcal{L}_H, \mathcal{L}_S, \mathcal{L}_T, \mathcal{L}_X, \mathcal{L}_Y$ for the strong decays to $D^{(*)}\pi, D^{(*)}\eta$ and $D_s^{(*)}K$ are written as [16, 17, 18, 19, 20]:

$$\begin{aligned} \mathcal{L}_H &= g_H \text{Tr} \{ \bar{H}_a H_b \gamma_\mu \gamma_5 \mathcal{A}_{ba}^\mu \}, \\ \mathcal{L}_S &= g_S \text{Tr} \{ \bar{H}_a S_b \gamma_\mu \gamma_5 \mathcal{A}_{ba}^\mu \} + h.c., \\ \mathcal{L}_T &= \frac{g_T}{\Lambda_\chi} \text{Tr} \{ \bar{H}_a T_b^\mu (iD_\mu \mathcal{A} + i\mathcal{D}\mathcal{A}_\mu)_{ba} \gamma_5 \} + h.c., \\ \mathcal{L}_X &= \frac{g_X}{\Lambda_\chi} \text{Tr} \{ \bar{H}_a X_b^\mu (iD_\mu \mathcal{A} + i\mathcal{D}\mathcal{A}_\mu)_{ba} \gamma_5 \} + h.c., \\ \mathcal{L}_Y &= \frac{1}{\Lambda_\chi^2} \text{Tr} \left\{ \bar{H}_a Y_b^{\mu\nu} [k_1 \{D_\mu, D_\nu\} \mathcal{A}_\lambda + k_2 (D_\mu D_\lambda \mathcal{A}_\nu + D_\nu D_\lambda \mathcal{A}_\mu)]_{ba} \gamma^\lambda \gamma_5 \right\} + h.c., \end{aligned} \quad (3)$$

where

$$\begin{aligned} \mathcal{D}_\mu &= \partial_\mu + \mathcal{V}_\mu, \\ \mathcal{V}_\mu &= \frac{1}{2} \left(\xi^\dagger \partial_\mu \xi + \xi \partial_\mu \xi^\dagger \right), \\ \mathcal{A}_\mu &= \frac{1}{2} \left(\xi^\dagger \partial_\mu \xi - \xi \partial_\mu \xi^\dagger \right), \end{aligned} \quad (4)$$

Λ_χ is the chiral symmetry-breaking scale and taken as $\Lambda_\chi = 1 \text{ GeV}$ [11], the strong coupling constants g_H, g_S, g_T, g_X and $g_Y = (k_1 + k_2)$ can be fitted phenomenologically if there are enough experimental data. The subscript indexes H, S, T, X and Y denote the interactions between the super-field H and the super-fields H, S, T, X and Y , respectively. We have smeared the superscripts $\iota, \text{''}, \text{'''}, \dots$ for simplicity, the notation g_H denotes the strong coupling constants in the vertexes $HH\mathcal{A}, H'H\mathcal{A}, H'H'\mathcal{A}, H''H\mathcal{A}, \dots$, the notations g_S, g_T, g_X and g_Y should be understood in the same way. In this article, we intend to study the ratios among different decay channels, the strong coupling constants are canceled out with each other, and cannot lead to confusion.

From the heavy meson chiral Lagrangians $\mathcal{L}_H, \mathcal{L}_S, \mathcal{L}_T, \mathcal{L}_X, \mathcal{L}_Y$, we can obtain the widths Γ for the strong decays to $D^{(*)}\pi, D^{(*)}\eta$ and $D_s^{(*)}K$ easily,

$$\Gamma = \frac{p_{cm}}{8\pi M^2} |T|^2, \quad (5)$$

where the T denotes the scattering amplitudes, the p_{cm} is the momentum of the final states in the center of mass coordinate.

In calculations, we take the approximation $\mathcal{A}_\mu \approx i \frac{\partial_\mu \mathcal{M}}{f_\pi}$. In the case that the light pseudoscalar meson momenta are not very small, we should add other terms and introduce new unknown coupling constants. Furthermore, the flavor and spin violation corrections of order $\mathcal{O}(1/m_Q)$ to the heavy quark limit may be sizable, again we should introduce

new unknown coupling constants, which will not necessarily canceled out in the ratios of the decay widths. We cannot estimate the role and the size of such corrections on general grounds, however, we expect that they would not be larger than (or as large as) the leading order contributions.

3 Numerical Results

The input parameters are taken from the particle data group $M_{\pi^+} = 139.57 \text{ MeV}$, $M_{\pi^0} = 134.9766 \text{ MeV}$, $M_{K^+} = 493.677 \text{ MeV}$, $M_{\eta} = 547.853 \text{ MeV}$, $M_{D^+} = 1869.60 \text{ MeV}$, $M_{D^0} = 1864.83 \text{ MeV}$, $M_{D_s^+} = 1968.47 \text{ MeV}$, $M_{D^{*+}} = 2010.25 \text{ MeV}$, $M_{D^{*0}} = 2006.96 \text{ MeV}$, $M_{D_s^{*+}} = 2112.3 \text{ MeV}$, $M_{D(2460)} = 2460.1 \text{ MeV}$ [4].

The numerical values for the widths of the strong decays

$$\begin{aligned} D_2^* &\rightarrow D^{*+}\pi^-, D^+\pi^-, \\ D' &\rightarrow D^{*+}\pi^-, D^{*0}\pi^0, \\ D^{*'}(D_1^*, D_2, D_3) &\rightarrow D^{*+}\pi^-, D^+\pi^-, D^{*0}\pi^0, D^0\pi^0, D^{*0}\eta, D^0\eta, D_s^{*+}K^-, D_s^+K^-, \end{aligned} \quad (6)$$

are presented in Tables 3-4.

In Table 5, we present the experimental data for the ratio $\frac{\Gamma(D^+\pi^-)}{\Gamma(D^{*+}\pi^-)}$ of the well established meson $D_2^*(2460)$ from the Babar [1], CLEO [21, 22], ARGUS [23], and ZEUS [24] collaborations, the prediction 2.30 from the heavy quark effective theory in the leading order approximation is in excellent agreement with the average experimental value 2.35. Compared with the experimental data from the Babar collaboration $\frac{\Gamma(D^+\pi^-)}{\Gamma(D^{*+}\pi^-)} = 1.47 \pm 0.03 \pm 0.16$ [1], the heavy quark effective theory in the leading order approximation leads to a larger ratio.

The total decay widths of the $(D(2550), D(2600))$ with the spin-parity $(0^-, 1^-)_{\frac{1}{2}}$ are $\Gamma_{D'} \approx 1.7g_H^2 \text{ GeV}$ and $\Gamma_{D^{*'}} \approx 2.0g_H^2 \text{ GeV}$, the ratio $\frac{\Gamma_{D'}}{\Gamma_{D^{*'}}} \approx 0.85$, which is smaller than the experimental data $\frac{\Gamma_{D'}}{\Gamma_{D^{*'}}} = 1.40$, where we have used the central values of the widths $\Gamma_{D'} \approx (130 \pm 12 \pm 13) \text{ MeV}$ and $\Gamma_{D^{*'}} = (93 \pm 6 \pm 13) \text{ MeV}$ from the Babar collaboration [1]. For the charmed mesons, the leading power flavor and spin violation corrections (of order $\mathcal{O}(1/m_Q)$) to the heavy quark limit may be sizable, we have to introduce new unknown coupling constants, the discrepancy may be smeared with the optimal parameters, furthermore, more precise measurements are needed to make a reliable comparison. In the case of the ratio $\frac{\Gamma_{D_1}}{\Gamma_{D_2^*}}$, the prediction 0.30 from the heavy quark effective theory in the leading order approximation is also smaller than the experimental data 0.48 from the Review of Particle Physics [4], if the leading power spin corrections to the heavy quark limit are taken into account, the discrepancy can be smeared [25].

The ratio $\frac{\Gamma(D^{*'} \rightarrow D^+\pi^-)}{\Gamma(D^{*'} \rightarrow D^{*+}\pi^-)} = 0.82$ from the heavy quark effective theory in the leading order approximation is larger than the experimental data $0.32 \pm 0.02 \pm 0.09$ from the Babar collaboration [1], just like in the case of the ratio $\frac{\Gamma(D_2^* \rightarrow D^+\pi^-)}{\Gamma(D_2^* \rightarrow D^{*+}\pi^-)}$, and again more precise measurements are needed to make a reliable comparison. The strong coupling constants $g_{D^*D\pi}$ and $g_{D^*D^*\pi}$ receive sizable contributions from the flavor and spin violation corrections [20, 26], in the present case, the strong coupling constants $g_{D^{*'}D\pi}$ and $g_{D^{*'}D^*\pi}$ also receive the flavor and spin violation corrections besides the leading order strong coupling

constant g_H , which maybe account for the discrepancy. We can tentatively identify the $(D(2550), D(2600))$ as the doublet $(0^-, 1^-)_{\frac{1}{2}}$ with $n = 2$.

The existing theoretical estimations for the strong coupling constant g_H among the ground state heavy mesons ($n = 1$) vary in a large range $g_H = 0.1 - 0.6$, it is difficult to select the ideal value (one can consult Ref.[27] for more literatures), we usually use the value determined from the precise experimental data on the decay $D^{*+} \rightarrow D^0 \pi^+$ from the CLEO collaboration [28, 29]. In the present case, the strong coupling constants involve the radial excited S -wave heavy mesons and ground state D -wave heavy mesons, therefor the situation is more involved, and it is impossible to determine the relevant parameters with the heavy quark effective theory itself without enough experimental data. The theoretical works focus on the strong coupling constants g_H, g_S, g_T of the ground state S -wave and P -wave heavy mesons (one can consult Refs.[20, 27, 30] for more literatures), while the works on the strong coupling constants g_H, g_S, g_T of the radial excited S -wave and P -wave heavy mesons and g_X, g_Y of the ground state D -wave heavy mesons are rare due to lack experimental data [31]. In this article, we take the strong coupling constants g_H, g_T, g_X and g_Y as unknown parameters, and prefer the ratios of the decay widths in different channels to compare with the experimental data.

From Table 4, we can see that if we identify the $(D(2760), D(2750))$ as the doublet $(1^-, 2^-)_{\frac{3}{2}}$ with $n = 1$, the ratio $\frac{\Gamma(D_1^+ \rightarrow D^+ \pi^-)}{\Gamma(D_2^+ \rightarrow D^{*+} \pi^-)} = 4.07$ from the leading order heavy quark effective theory deviates from the experimental data $0.42 \pm 0.05 \pm 0.11$ greatly [1]², which requires the flavor and spin violation corrections depressed by the inverse heavy quark mass $1/m_Q$ are as large as the leading order contributions and have opposite sign, it is impossible, as the heavy quark effective theory has given many successful descriptions of the hadron properties [2, 3, 20]. On the other hand, if we identify the $(D(2750), D(2760))$ as the doublet $(2^-, 3^-)_{\frac{5}{2}}$ with $n = 1$, the deviation of the ratio $\frac{\Gamma(D_3 \rightarrow D^+ \pi^-)}{\Gamma(D_2^{*+} \rightarrow D^{*+} \pi^-)} = 0.80$ from the upper bound of the experimental data $0.42 \pm 0.05 \pm 0.11$ is not large [1], the contributions from the flavor and spin violation corrections maybe smear the discrepancy.

We also explore the possible identification of the $D(2760)$ and $D(2750)$ as the same 3^- state with $n = 1$, i.e. they are the D_3 state, the ratio $\frac{\Gamma(D_3 \rightarrow D^+ \pi^-)}{\Gamma(D_3 \rightarrow D^{*+} \pi^-)} = 1.94$ from the heavy quark effective theory in the leading order approximation is too large compared with the experimental data $\frac{\Gamma(D(2760)^0 \rightarrow D^+ \pi^-)}{\Gamma(D(2750)^0 \rightarrow D^{*+} \pi^-)} = 0.42 \pm 0.05 \pm 0.11$ [1], which again requires the flavor and spin violation corrections depressed by the inverse heavy quark mass $1/m_Q$ are as large as the leading order contributions and have opposite sign, such an identification is disfavored. On the other hand, the helicity distribution disfavors identifying the $D(2750)$ as the 3^- state [1]. We can tentatively identify the $(D(2750), D(2760))$ as the doublet $(2^-, 3^-)_{\frac{5}{2}}$ with $n = 1$.

In this article, we also present the widths for the $D_s^{(*)}K$ and $D^{(*)}\eta$ decays, where the strong coupling constants are retained, the predictions can be confronted with the experiential data in the future at the BESIII, KEK-B, RHIC, PANDA and LHCb.

²We take the approximation $\Gamma_{D(2760)} = \Gamma_{D(2750)}$.

	$n L s_\ell J^P$	Mass [MeV]	Decay channels	Width [GeV]
D_2^*	$1 P \frac{3}{2} 2^+$	2460.1	$D^{*+}\pi^-; D^+\pi^-$	$0.0543879g_T^2; 0.124928g_T^2$
D'	$2 S \frac{1}{2} 0^-$? 2539.4	$D^{*+}\pi^-; D^{*0}\pi^0$	$1.13557g_H^2; 0.583137g_H^2$
$D^{*'} $	$2 S \frac{1}{2} 1^-$? 2608.7	$D^{*+}\pi^-; D^+\pi^-$ $D_s^{*+}K^-; D_s^+K^-$ $D^{*0}\pi^0; D^0\pi^0$ $D^{*0}\eta; D^0\eta$	$0.66068g_H^2; 0.54317g_H^2$ $0.000518592g_H^2; 0.106459g_H^2$ $0.336747g_H^2; 0.276487g_H^2$ $0.00841286g_H^2; 0.029364g_H^2$
D_1^*	$1 D \frac{3}{2} 1^-$? 2763.3	$D^{*+}\pi^-; D^+\pi^-$ $D_s^{*+}K^-; D_s^+K^-$ $D^{*0}\pi^0; D^0\pi^0$ $D^{*0}\eta; D^0\eta$	$0.339606g_X^2; 5.19392g_X^2$ $0.0632191g_X^2; 1.86912g_X^2$ $0.173223g_X^2; 2.65247g_X^2$ $0.0226441g_X^2; 0.508904g_X^2$
D_2	$1 D \frac{3}{2} 2^-$? 2752.4	$D^{*+}\pi^-; D^+\pi^-$ $D_s^{*+}K^-; D_s^+K^-$ $D^{*0}\pi^0; D^0\pi^0$ $D^{*0}\eta; D^0\eta$	$1.27691g_X^2; 0$ $0.180643g_X^2; 0$ $0.653307g_X^2; 0$ $0.069308g_X^2; 0$
$D_2^{*'} $	$1 D \frac{5}{2} 2^-$? 2752.4	$D^{*+}\pi^-; D^+\pi^-$ $D_s^{*+}K^-; D_s^+K^-$ $D^{*0}\pi^0; D^0\pi^0$ $D^{*0}\eta; D^0\eta$	$0.221226g_Y^2; 0$ $0.00413833g_Y^2; 0$ $0.114719g_Y^2; 0$ $0.0027123g_Y^2; 0$
D_3	$1 D \frac{5}{2} 3^-$? 2763.3	$D^{*+}\pi^-; D^+\pi^-$ $D_s^{*+}K^-; D_s^+K^-$ $D^{*0}\pi^0; D^0\pi^0$ $D^{*0}\eta; D^0\eta$	$0.0907266g_Y^2; 0.176388g_Y^2$ $0.00218128g_Y^2; 0.018115g_Y^2$ $0.0468994g_Y^2; 0.0912646g_Y^2$ $0.00124089g_Y^2; 0.00618076g_Y^2$

Table 3: The strong decay widths of the newly observed charmed mesons with possible identifications.

	$n L s_\ell J^P$	Mass [MeV]	Ratio
D_2^*	$1 P \frac{3}{2} 2^+$	2460.1	$\frac{\Gamma(D^+\pi^-)}{\Gamma(D^{*+}\pi^-)} = 2.30$
$D^{*'} $	$2 S \frac{1}{2} 1^-$? 2608.7	$\frac{\Gamma(D^+\pi^-)}{\Gamma(D^{*+}\pi^-)} = 0.82$; $\frac{\Gamma(D^{*0}\pi^0)}{\Gamma(D^{*+}\pi^-)} = 0.51$; $\frac{\Gamma(D^0\pi^0)}{\Gamma(D^{*+}\pi^-)} = 0.42$; $\frac{\Gamma(D_s^+K^-)}{\Gamma(D^{*+}\pi^-)} = 0.16$; $\frac{\Gamma(D^0\eta)}{\Gamma(D^{*+}\pi^-)} = 0.044$; $\frac{\Gamma(D^{*0}\eta)}{\Gamma(D^{*+}\pi^-)} = 0.013$; $\frac{\Gamma(D_s^{*+}K^-)}{\Gamma(D^{*+}\pi^-)} = 0.001$
D_1^*	$1 D \frac{3}{2} 1^-$? 2763.3	$\frac{\Gamma(D^+\pi^-)}{\Gamma(D^{*+}\pi^-)} = 15.29$; $\frac{\Gamma(D^0\pi^0)}{\Gamma(D^{*+}\pi^-)} = 7.81$; $\frac{\Gamma(D_s^+K^-)}{\Gamma(D^{*+}\pi^-)} = 5.50$; $\frac{\Gamma(D^0\eta)}{\Gamma(D^{*+}\pi^-)} = 1.50$; $\frac{\Gamma(D^{*0}\pi^0)}{\Gamma(D^{*+}\pi^-)} = 0.51$; $\frac{\Gamma(D_s^{*+}K^-)}{\Gamma(D^{*+}\pi^-)} = 0.19$; $\frac{\Gamma(D^{*0}\eta)}{\Gamma(D^{*+}\pi^-)} = 0.067$
D_2	$1 D \frac{3}{2} 2^-$? 2752.4	$\frac{\Gamma(D^{*0}\pi^0)}{\Gamma(D^{*+}\pi^-)} = 0.51$; $\frac{\Gamma(D_s^{*+}K^-)}{\Gamma(D^{*+}\pi^-)} = 0.14$; $\frac{\Gamma(D^{*0}\eta)}{\Gamma(D^{*+}\pi^-)} = 0.054$
$D_2^{*'} $	$1 D \frac{5}{2} 2^-$? 2752.4	$\frac{\Gamma(D^{*0}\pi^0)}{\Gamma(D^{*+}\pi^-)} = 0.52$; $\frac{\Gamma(D_s^{*+}K^-)}{\Gamma(D^{*+}\pi^-)} = 0.019$; $\frac{\Gamma(D^{*0}\eta)}{\Gamma(D^{*+}\pi^-)} = 0.012$
D_3	$1 D \frac{5}{2} 3^-$? 2763.3	$\frac{\Gamma(D^+\pi^-)}{\Gamma(D^{*+}\pi^-)} = 1.94$; $\frac{\Gamma(D^0\pi^0)}{\Gamma(D^{*+}\pi^-)} = 1.01$; $\frac{\Gamma(D^{*0}\pi^0)}{\Gamma(D^{*+}\pi^-)} = 0.52$; $\frac{\Gamma(D_s^+K^-)}{\Gamma(D^{*+}\pi^-)} = 0.20$; $\frac{\Gamma(D^0\eta)}{\Gamma(D^{*+}\pi^-)} = 0.068$; $\frac{\Gamma(D_s^{*+}K^-)}{\Gamma(D^{*+}\pi^-)} = 0.024$; $\frac{\Gamma(D^{*0}\eta)}{\Gamma(D^{*+}\pi^-)} = 0.014$
D_1^*	$1 D \frac{3}{2} 1^-$? 2763.3	$\frac{\Gamma(D_1^* \rightarrow D^+\pi^-)}{\Gamma(D_2 \rightarrow D^{*+}\pi^-)} = 4.07$
D_2	$1 D \frac{3}{2} 2^-$? 2752.4	
$D_2^{*'} $	$1 D \frac{5}{2} 2^-$? 2752.4	$\frac{\Gamma(D_3^* \rightarrow D^+\pi^-)}{\Gamma(D_2^{*'} \rightarrow D^{*+}\pi^-)} = 0.80$
D_3	$1 D \frac{5}{2} 3^-$? 2763.3	

Table 4: The ratios of the strong decay widths of the newly observed charmed mesons with possible identifications.

Babar	CLEO	CLEO	ARGUS	ZEUS	This work
$1.47 \pm 0.03 \pm 0.16$	$2.2 \pm 0.7 \pm 0.6$	2.3 ± 0.8	$3.0 \pm 1.1 \pm 1.5$	$2.8 \pm 0.8^{+0.5}_{-0.6}$	2.30

Table 5: The ratio of $\frac{\Gamma(D_2^*(2460)^0 \rightarrow D^+\pi^-)}{\Gamma(D_2^*(2460)^0 \rightarrow D^{*+}\pi^-)}$ from the experimental data compared with the prediction from the leading order heavy quark effective theory.

4 Conclusion

In this article, we study the strong decays of the newly observed charmed mesons $D(2550)$, $D(2600)$, $D(2750)$ and $D(2760)$ with the heavy quark effective theory in the leading order approximation, and tentatively identify the $(D(2550), D(2600))$ as the doublet $(0^-, 1^-)$ with $n = 2$ and $(D(2750), D(2760))$ as the doublet $(2^-, 3^-)$ with $n = 1$, respectively. The identification of the $D(2750)$ and $D(2760)$ as the same particle with $J^P = 3^-$ is disfavored. The other predictions can be confronted with the experimental data in the future at the BESIII, KEK-B, RHIC, PANDA and LHCb.

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